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Numerical simulation and experimental investigation of submersible sewage mixer performance

Błoński D. Szulc P. Machalski A. Rogula J.
^{1}Wroclaw Univesity of Science and Technology

Introduction

Submersible mixers are machines that are widely utilized in urban and rural sewage treatment farms. They play the most important role biochemical reactions such as anaerobic digestion, sedimentation and wastewater aeration [1-2]. Fluid mixing is a very complicated process that has not fully been developed. So far none algorithms for high efficiency submersible mixer design were found. Therefore, there is a strong desire for creating a methodology for designing and validation of machine flowpath.

Since these machines work 24/7, they should be characterized by the highest efficiency of the mixing process.Cost of electrical energy consumption is the main operating cost of wastewater treatment plants. Trying to minimize overall operational cost, one can put forward a thesis that using more advanced blade design will result in energy consumption reduction that can overcome its higher purchase price. In this work, the authors focus on presenting results from experimental, numerical and theoretical evaluation of sewage mixer performance. Poster is divided into three sections. First part concerns about experimental setup and results. Next, numerical simulation is discussed. Finally comparison of experimental, numerical and theoretical performance evaluation is done.

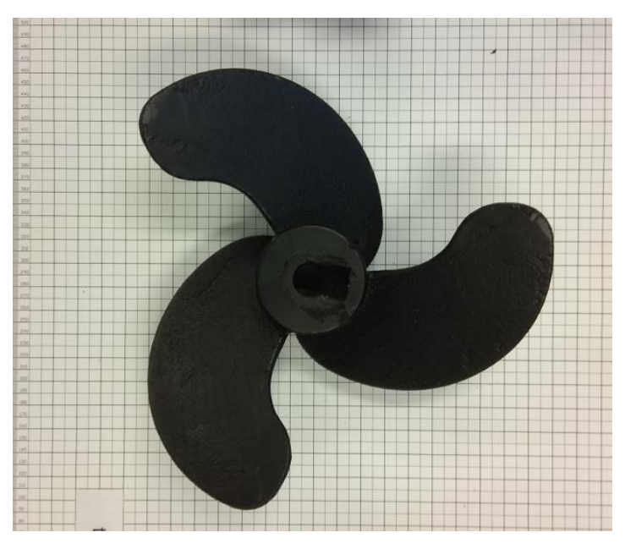

Figure 1. Sewage mixer propeller and test rig

Measurements

Thrust and Power on the shaft are main variables to evaluate machine efficiency. According to [3] the efficiency of the mixer can be calculated with equation

$$\eta = \frac{9.55 F_T^{\frac{3}{2}}}{40dMn}.$$

The efficiency of the mixer is proportional to the 3/2 power of water thrust F_T, inversely proportional to the blade diameter d, and inversely proportional to the shaft power of the submersible mixer. Thrust is the most important performance parameter of the mixer. It is essential for correct equipment selection. Factory testing is done in accordance with the relatively new ISO 21630 standard released in 2007. Thrust is considered as a rate of axial momentum imposed on water. It can be evaluated by measured velocity field integration or by measuring reaction force of the mixer. The second approach was used in our test rig (Fig. 1.). The measurement of reaction force bases on the lever principal, where reaction forces are measured with load cells.

Test rig

The mixer (1) is suspended on a pivot (4) and connected to the frame (2) with a force transducer (5) (Fig.2). Axis of pivot is perpendicular to axis of mixer rotation. In order to calculate the thrust force a simple proportion equation can be used. Same approach has been utilized for torque measurement. Here, the cage is suspended on bearing (3) that parallel to axis of mixer rotation. The torque is measured with another load cell (8). All data is collected with data acquisition module (7). Measurement of electrical power is done with network meter (6) and then transferred to computer.

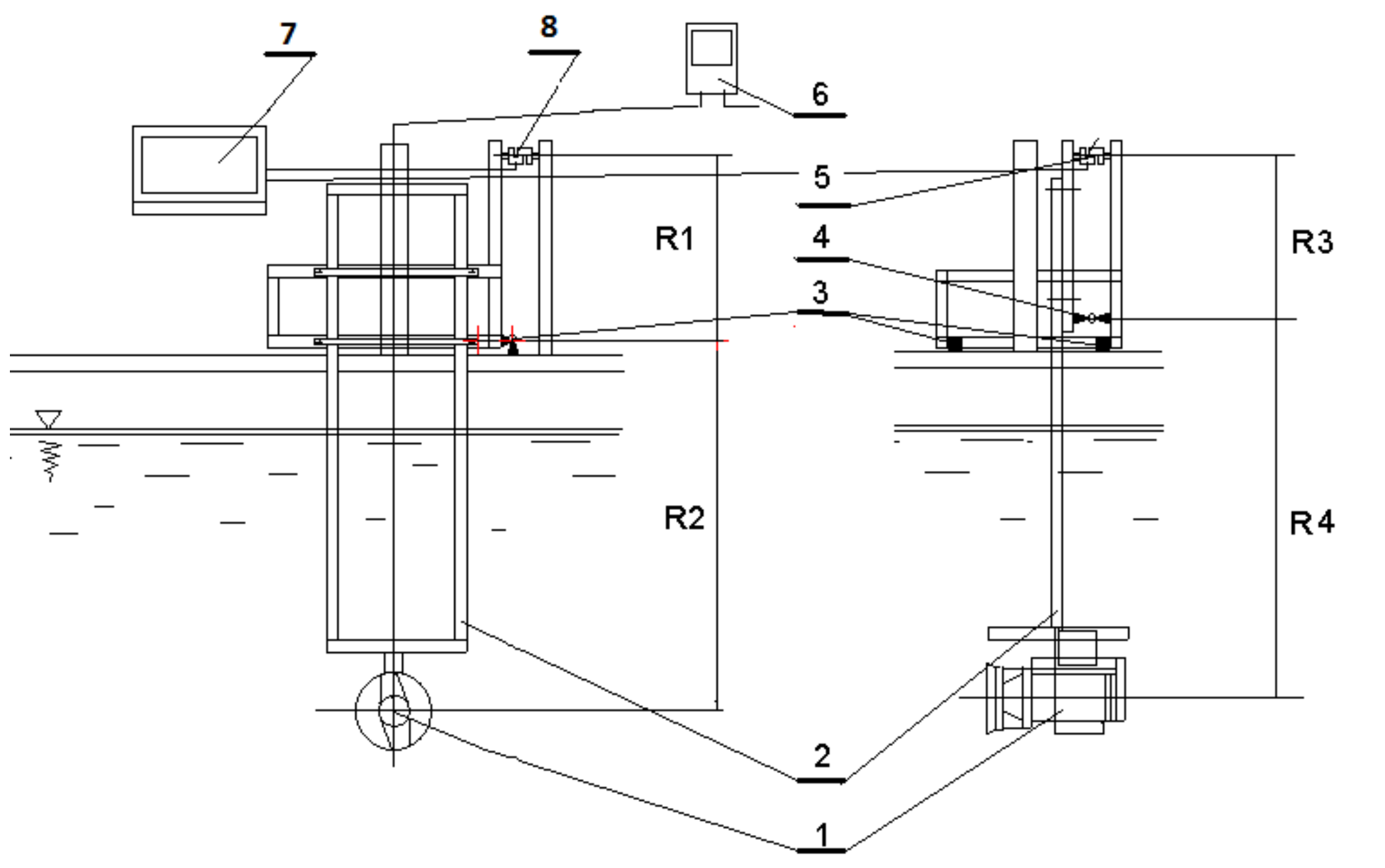

Figure 2. Test rig schematics

Numerical simulation

Numerical simulation was conducted as steady RANS for the determined boundary conditions. Ansys Fluent SIMPLE solver was utilized. The medium was defined as clear water. For the turbulence SST model was selected. The unstructured tetrahedral mesh was used and it consisted of 44 million elements (Fig. 3). Boundary layer on the blades has been resolved to keep y+<1. Mass flow rate was not explicitly determined, therefore a first order upwind approximation for momentum was used to faciliate convergance. For turbulence second order upwind approximations were utilized. Pressure was also second order. Gradients were calculated with least square based method.

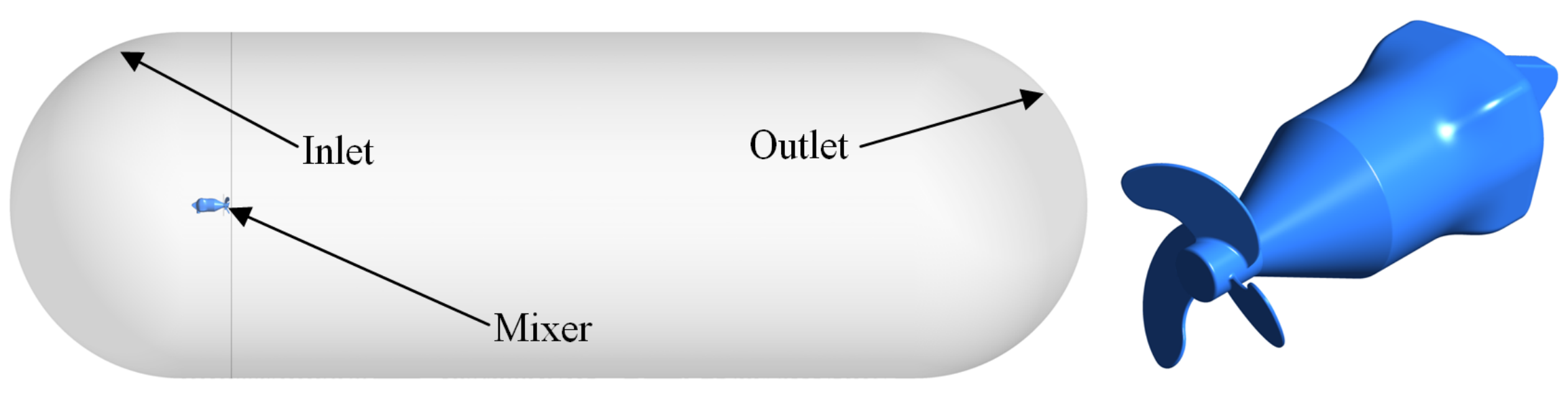

Figure 3. Computational domain

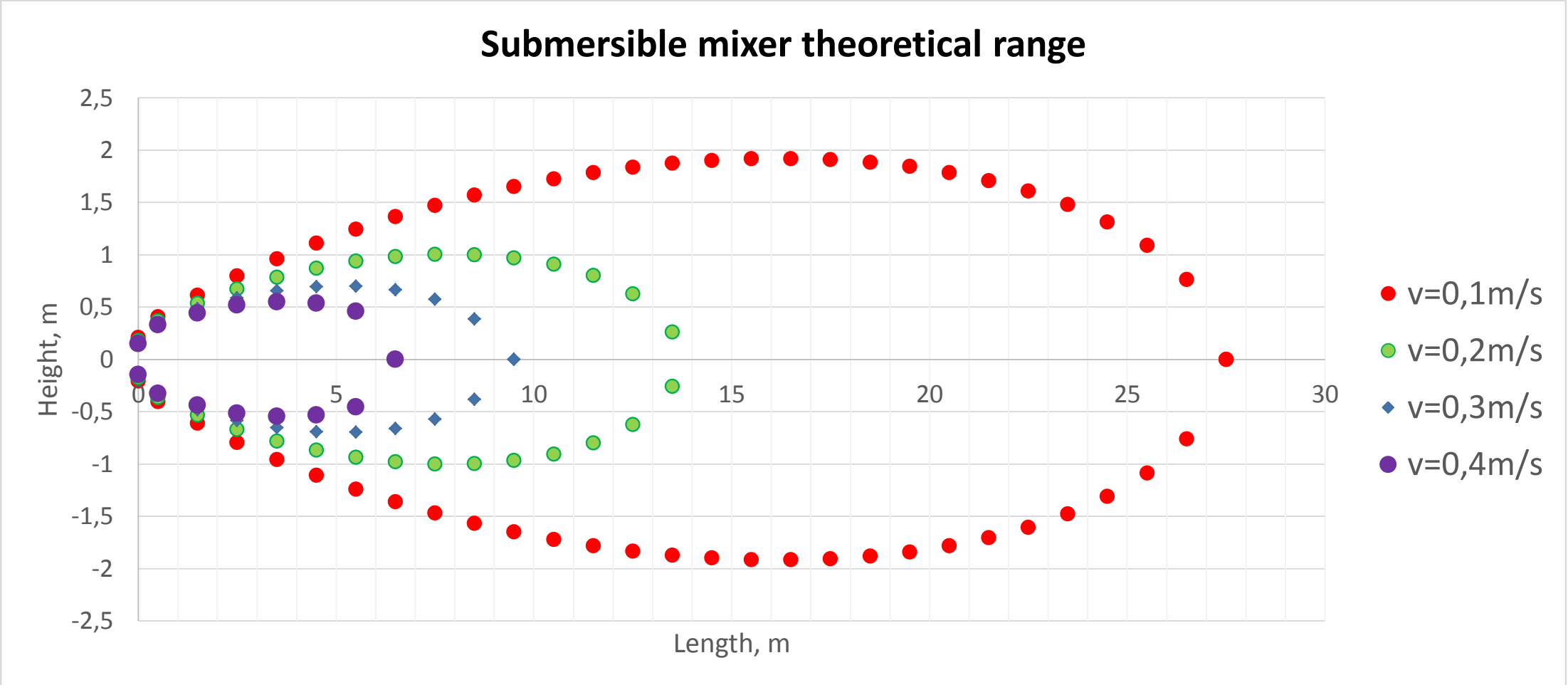

Figure 4. Theoretical range.

Results

The error is equal 1,6% and 5,2% for thrust and torque respectively. It should be noticed that the downgrade in approximation order did not affect the overall accuracy for mixer performance evaluation. Proposed numerical simulation approach is sufficient for most new units design.(Table 1.)

Comparison of theoretical [4] and numerical approach shows that both methods are not consistent. In respect to simulation results the values for high velocity flow are overestimated. The value low velocity is underestimated. (Fig 4-5., Table 2.)

Table 1. CFD and experiment comparison

	CFD	Exp.	Error
Thrust force	453,2 N	460,7 N	1,6%
Mean shaft	28,19Nm	29,73Nm	5,2%
Revolutions per minute	738,5 1/min	738,5 1/min	0%

Table 2. Theoretical and CFD mixer range

	CFD	Theory	Difference
v=0,2m/s	>16m	14,08m	>12%
v=0,3m/s	9,01m	9,12m	1,2%
v=0,4m/s	5,24m	6,84m	30,5%

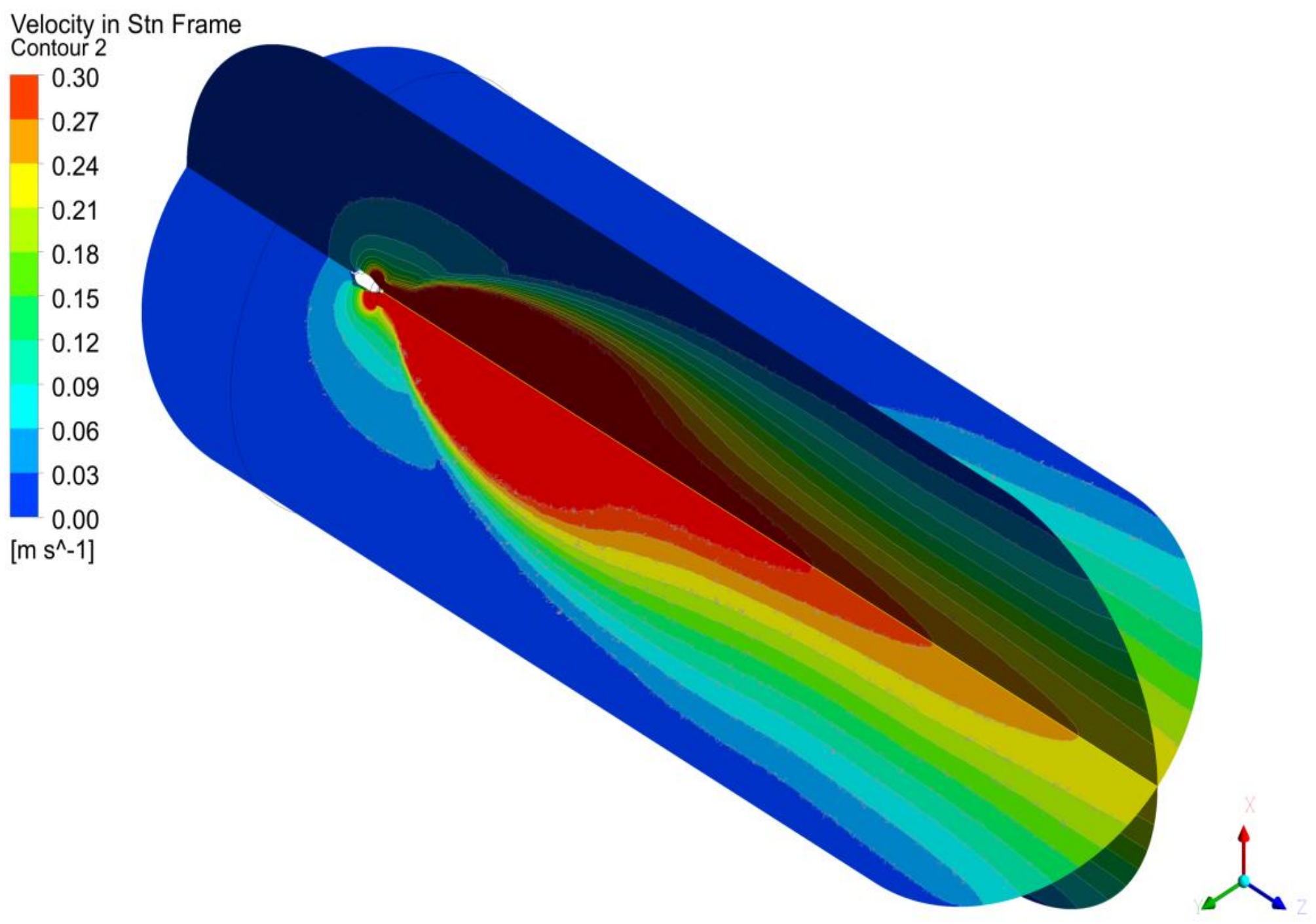

Figure 5. Velocity distribution in computational domain.

Conclusions

The comparison between experiment and numerical simulation showed that a downgrade of order of accuracy for momentum equation did not affected consistency of the results. Calculated torque and thrust values was showed good agreement with experiment. Comparison between theoretical and numerical values of submersible mixer revealed that there obtained results vary, but a theoretical approach can be useful for initial parameters guess.

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Speaker:
Dominik Błoński, Professor, Wroclaw University of Science and Technology,
Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland
dominik.blonski@pwr.edu.pl,